

New Cretaceous turbiniform vetigastropods (Gastropoda) from the Pacific slope of North America

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ABSTRACT

Seven new species of warm-temperate, shallow-marine turbiniform vetigastropods are described from Cretaceous strata in the region extending from Vancouver Island, British Columbia, to northern Baja California, Mexico. The chilodontine *Agathodonta haegerti* new species (latest Santonian) is the first confirmed species of this extant genus in the Western Hemisphere. The ealliotropine *Cidarina grahami* new species (middle Campanian) is the earliest record of this extant genus. The colloniines *Afrollonia elderensis* new species (late Albian) and *Antilocollonia bos* new species (Turonian) are the earliest records of these extant genera in Western Hemisphere. The teguline *Tegula daileyi* new species (late Campanian) is one of the few known Campanian species of this extant genus. The margaritines *Pupillaria encina* new species and *Pupillaria lomana* new species (both of which are late Campanian to possibly early Maastrichtian in age) are the earliest records of this extant genus.

During the course of this study, it was discovered that the nododelphinulid *Trochacanthus wallalense* (White, 1885) (late Campanian to early late Maastrichtian) is the senior synonym of *T. pacificus* Squires and Saul, 2001. White's species is the only known occurrence of this extinct genus in the Western Hemisphere.

Additional keywords: Amberleyoidea, Seguenzioidea, Turbinoidea

rare. The significance of this study is that the species represent either the earliest record of their genus or the first record of their genus in the Western Hemisphere. In addition to the description of the new species, their biostratigraphy is established. During the course of this study, it was discovered also that *Trochacanthus wallalense* (White, 1885), is the senior synonym of *Trochacanthus pacificus* Squires and Saul, 2001. The first photographs of White's holotype are provided here, as well as the morphologic redescription and geologic age refinement of his species.

The designated areas (e.g., Area 3) where the species were collected are shown on Figure 1. The details of the type localities are given in Appendix 1. As discussed by Saul and Squires (2008) and Squires and Saul (2009), localities west of the San Andreas Fault have been tectonically transported, and localities in British Columbia most likely have been tectonically transported from northern California. The temporal ranges of all the studied species are plotted on Figure 2. Their combined Cretaceous record in the study area spans the middle Albian to late Maastrichtian, an interval of approximately 38 million years. The paleoclimate that prevailed in the study area when the new species lived was generally warm temperate (Saul and Squires, 2008; Squires and Saul, 2009).

MATERIALS AND METHODS

This study is based on 65 specimens borrowed from museum collections. Preservation of the shell material is generally good, but nearly all the nacre has been replaced by calcite. Knowledge about the umbilical area is critical in distinguishing turbiniform-vetigastropod taxa. Some of the specimens already were already cleaned by L. R. Saul and the late W. P. Popenoe. A few additional specimens were cleaned by the author and L. R. Saul. The cleaning was done mainly by means of a

INTRODUCTION

This study concerns turbiniform vetigastropods from shallow-marine Cretaceous rocks in the region extending from Vancouver Island, British Columbia, Canada, to northern Baja California, Mexico (Figure 1). These gastropods comprise eight genera and eight species; seven of the species are new. Nearly all of the species are very

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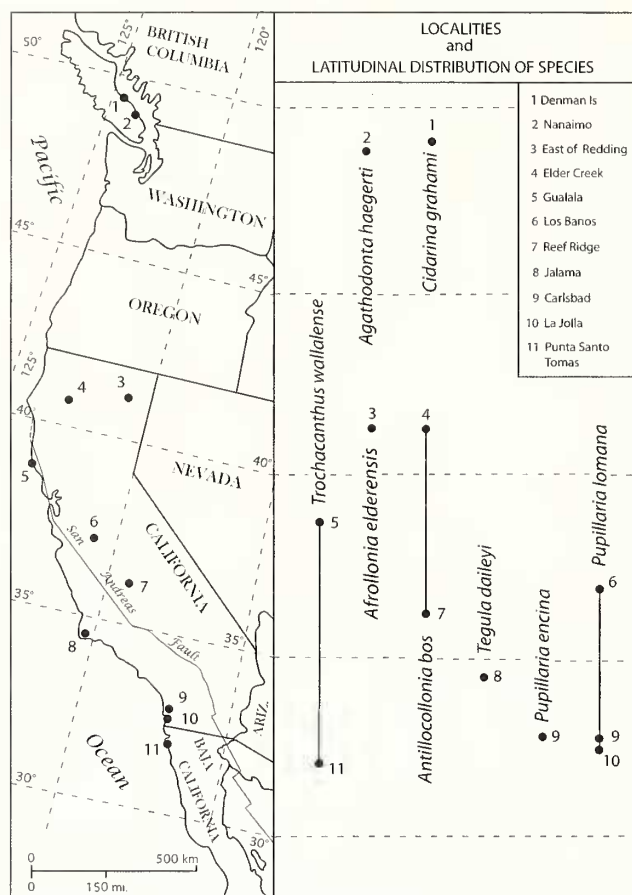


Figure 1. Localities map and latitudinal distribution of the studied trochiform vetigastropods.

high-speed drill with diamond-coated grinding wheels, but, it was also necessary to use hand-held, very sharp needles to clean the umbilical area on some of the smaller specimens.

The sequence of the treatment of the studied taxa in the "Systematic Paleontology" section mainly follows the classification scheme of Warén and Bouhet in Bouhet and Roeroi (2005: 243–245), modified to include the results from Williams et al. (2008). Most of the morphologic terms follow the usage of Cox (1960). The term "periumbilical cord" (i.e., a spiral cord extending from the parietal region downward to the columellar lip) follows the usage of Monari et al. (1996).

Current summaries of the geological details of the formations and members containing the studied specimens can be found in the following papers (listed in ascending chronostratigraphic order): Venado Sandstone (Squires and Saul, 2004a); Redding Formation, Bellavista Sandstone and Frazier Siltstone members (Squires and Saul, 2003a); Panoche Formation in Arroyo Pinoso, Reef Ridge area (Stewart, 1946); upper Haslam Formation (Squires and Saul, 2001); upper Cedar District Formation, west side of Denman Island (Squires and Saul, 2006); Jalama Formation (Squires and Saul, 2003b); Rosario Formation (Squires and Saul, 2001);

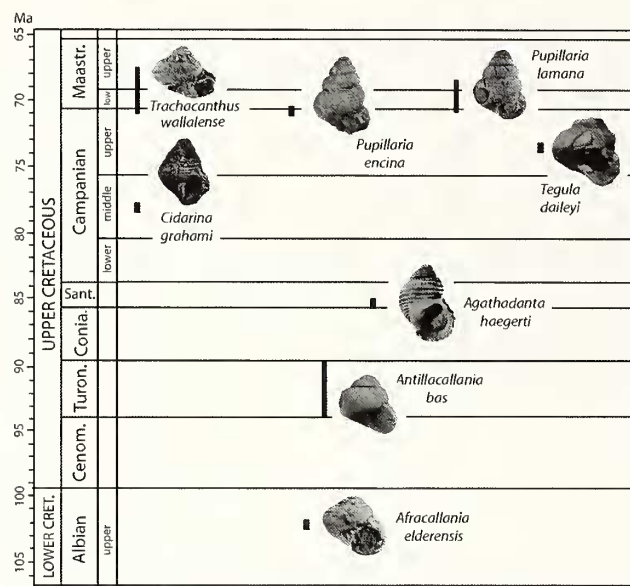


Figure 2. Geologic ranges of the studied species. Ages of stage boundaries from Gradstein et al. (2004).

Point Loma Formation (Squires and Saul, 2001); Cabrillo Formation (Squires and Saul, 2009); Gualala Formation (Squires and Saul, 2004b); and Moreno Formation, "Garzas Sand" and "Quinto Silt" members (Squires and Saul, 2003b).

Abbreviations used for catalog and locality numbers are: LACM, Natural History Museum of Los Angeles County, Invertebrate Paleontology Section (LACMIP); RBCM, Royal British Columbia Museum, Victoria; SDSNH, San Diego Society of Natural History; UCMP, University of California Museum of Paleontology (Berkeley); and USNM, National Museum of Natural History, Smithsonian Institution.

SYSTEMATIC PALEONTOLOGY

Clade Vetigastropoda Salvini-Plawen, 1980

Superfamily Ammerleyoidea Wenz, 1938

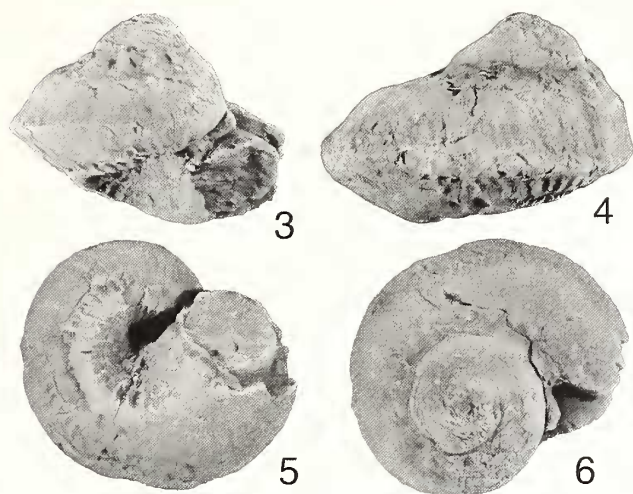
Family Nododelphinulidae Cox, 1960

Genus *Trochacanthus* Dacqué, 1936

Type Species: *Trochus tuberculatocinctus* Münster in Goldfuss, 1844, by subsequent designation (Wenz, 1938); Late Cretaceous, Europe (Poland and Germany).

Description: Shell size small to medium. Turbinate. Phaneromphalous. Spire whorls with strong collabral ribs. Last whorl (on adults) deviantly coiled relative to spire whorls. Last whorl with single keel coincident with periphery. Umbilicus bearing thin radiating ribs separated by sunken areas.

Discussion: Except for *Trochacanthus wallalense* (White, 1885), discussed below, the only other occurrences



Figures 3–6. *Trochacanthus wallalense* (White, 1885), holotype USNM 13412, from near Gualala, California, height 16.7 mm, diameter 21.5 mm. 3. Apertural view. 4. Abapertural view. 5. Umbilical view. 6. Apical view.

of this genus are from Santonian to Maastrichtian rocks of western Germany and lower Campanian to upper Maastrichtian rocks of central Poland (Dacqué, 1936; Kollmann, 1985; Abel-Gawad, 1986).

***Trochacanthus wallalense* (White, 1885)**
(Figures 3–6)

Solarium wallalense White, 1885: 14, pl. 5, figs. 1, 2.
Trochacanthus pacificus Squires and Saul, 2001: 49, 51, fig. 3.6–3.11.

Holotype: USNM 13412, height 16.7 mm, diameter 21.5 mm.

Type Locality: Near the town of Gualala [= Wallala of White (1885)], Mendocino County, northern California.

Geologic Age: Late Campanian to early late Maastrichtian.

Distribution: Gualala Formation, Mendocino County, northern California (Area 5); Moreno Formation, informal Quinto member, Los Banos area, Stanislaus County, northern California (Area 6); Point Loma Formation, Carlsbad, San Diego County, southern California (Area 9); Rosario Formation, Punta Santo Tomas [= Puerto Santo Tomas], Baja California, Mexico (Area 11).

Discussion: The holotype of this species, which is a weathered specimen whose sculpture on the spire is not well preserved, is photographed here for the first time, with more views than White (1885) provided in his sketches. Prior to this present report, this species was known only from its type locality in the Gualala Formation in Mendocino County and [as *T. pacificus*] from the Point Loma Sandstone in San Diego County. Additional single specimens were detected during this present investigation in collections from the Moreno Formation

(UCMP loc. A-3224) in Merced County, California and from the Rosario Formation (UCMP loc. A-6274) at Punta Santo Tomas, Baja California, Mexico.

Superfamily Seguenzioidea Verrill, 1884

Family Chilodontidae Wenz, 1938

Subfamily Chilodontinae Wenz, 1938

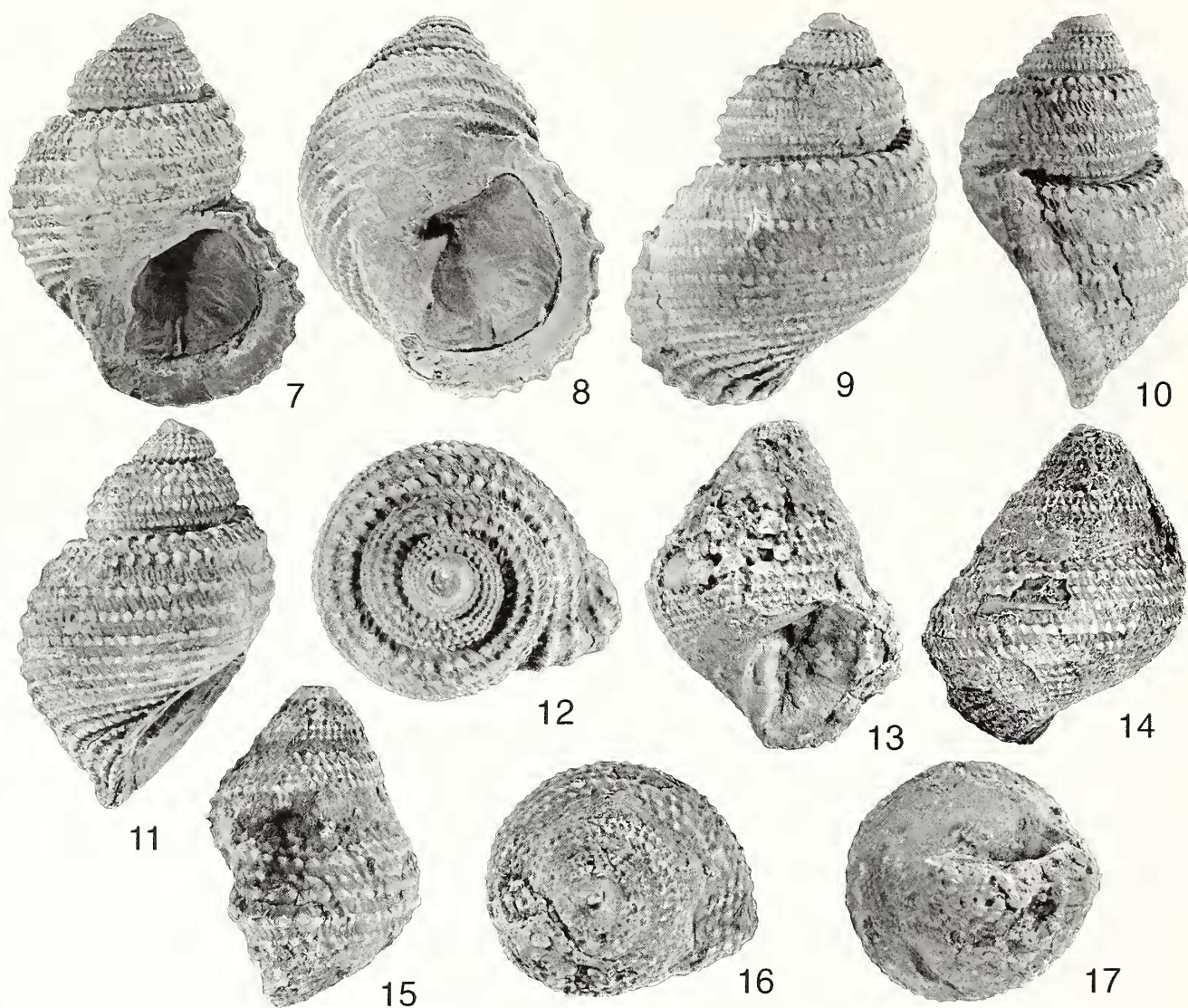
Genus ***Agathodonta* Cossmann, 1918**

Type Species: *Agathodonta elegans* (Deshayes in Leymerie, 1842 [= *Trochus dentigerus* d'Orbigny, 1842: 185, pl. 177, figs. 9–12]), by subsequent designation (Kollmann, 2005: 70–71); Early Cretaceous (Hauterivian), France.

Description: Shell size small to medium (height 10 to 34 mm). High fusiform. Suture deeply indented. Whorls deviantly coiled. Spiral cords strong and beaded to granulose. Outer lip variced and strongly prosoline; interior of lip thickened by apertural ridge with lira. Parietal callus well developed. Columella with two widely separated teeth, posterior tooth strongest and located posteriorly up into aperture. Pustules can be present anterior to anterior tooth on columella shield (at anterior end of columella). Opereulum chitinous. Interior nacreous.

Discussion: Prior to work by Kollmann (2005: 70–71), earlier workers cited the type species of *Agathodonta* as being *Trochus dentigerus* d'Orbigny, 1842, from France. Cossmann (1918: 200–201, pl. 7, figs. 8–11) discussed and figured this species, which he identified as *Chilodonta* (*Agathodonta*) *dentigera*. Wenz (1938: 298, fig. 653) illustrated the holotype, which he identified as *Agnathodonta* [sic] *dentigera*. Cox (1960: 249, fig. 160, 2) also figured the holotype, and like Wenz, considered *Agathodonta* to be a distinct genus within the chilodontines. Cossmann (1918) and Wenz (1938) reported the range of *Agathodonta* to be Neocomian to Albian, but McLean (1984) established that this chilodontine genus ranges into the Recent, where it is represented by a single species (see also Hickman and McLean, 1990: fig. 40E) from archibenthal (300 m) depths in the Philippines.

Based on its overall shape and sculpture, the new genus is very similar to the chilodontine *Danilia* Brusina, 1865, whose type species is the extant *Monodonta tinci* Calceara, 1839, from the Mediterranean Sea. Wenz (1938: 273, fig. 572) illustrated the holotype. Beu and Climo (1974) reported that *Danilia* ranges from Albian to Recent, with the fossil species mainly of Cenomanian age in Europe. They reviewed the taxonomy of *Danilia*, compared its fossil and Recent species, and illustrated two modern species of this genus from New Zealand. *Agathodonta* differs from *Danilia* by having two columellar teeth instead of just one, teeth not showing a notched appearance, and (on some species) no pustules on columellar shield. *Agathodonta* superficially resembles the calliotropine *Cidarina* Dall, 1909 in terms of shape and sculpture, but the latter is smaller and does not have any columellar teeth or a flared outer lip.



Figures 7–17. New eliolodontine and new calliotropine. Specimens coated with ammonium chloride. **7–12.** *Agathodonta haegerti* new species, holotype RBCM.EH2008.011.06500, Nanaimo area, British Columbia, height 33 mm, diameter 23 mm. **7.** Apertural view. **8.** Oblique apertural view. **9.** Abapertural view. **10.** Right-lateral view. **11.** Left-lateral view. **12.** Apical view. **13–17.** *Cidarina grahami* new species, holotype RBCM.EH2010.004.00001, west shore of Denman Island, British Columbia, height 18 mm, diameter 13.5 mm. **13.** Apertural view. **14.** Abapertural view. **15.** Right-lateral view. **16.** Apical view. **17.** Anterior (ventral) view.

Based on reports by earlier workers (Cossmann, 1918: 200; Wenz, 1938: 298; Keen, 1960: 1249; McLean, 1984; and Kollmann, 2005: 70–71), the geologic range of *Agathodonta* is Early Cretaceous (Hauterivian to Albian) to Recent, with its fossil occurrences restricted to Europe. *Agathodonta haegerti* new species, discussed below, is of latest Santonian age in British Columbia and is the first confirmed species of this genus in the Western Hemisphere.

***Agathodonta haegerti* new species**
(Figures 7–12)

Description: Shell size medium small (height 34 mm, diameter 22 mm, same specimen). Height approximately

1.5 times greater than shell diameter. Ovate conical. Anomphalous. Spire elevated, height approximately 20% (estimated) of shell height. Pleural angle approximately 75°. Protoconch and uppermost spire unknown. Teleoconch at least four whorls. Suture deeply impressed, almost emarginate. Coiling deviant. Whorls inflated, rounded. Shoulder very narrow. Sculpture of strong widely spaced spiral ribs: four ribs on antepenultimate whorl, six on penultimate whorl, and 14 on last whorl. Interspaces between spiral ribs usually uniformly twice as wide as ribs, except near shoulder where interspaces are three times as wide as ribs. Spiral ribs on antepenultimate whorl uniformly beaded; posteriormost two spiral ribs noded on penultimate and last whorl.

other spiral ribs beaded. Aperture large, elliptical. Outer lip with varix; interior of outer lip flared and smoothish. Inner lip with two widely separated teeth, posterior tooth strongest and located posteriorly up into aperture. Columellar shield present in parietal area and smooth, widening posteriorward. Growth lines prosocline. Interior nacreous.

Holotype: RBCM.EH2008.011.06500, height 33 mm, diameter 23 mm.

Type Locality: Locality 1 (see Appendix 1).

Geologic Age: Latest Santonian.

Distribution: Haslam Formation, upper part, just west of Nanaimo, east coast of Vancouver Island, British Columbia (Area 2).

Etymology: The species is named for Joe Haegert who collected the holotype.

Discussion: The new species is based on a single specimen. It is well preserved and is most similar to the extant *Agathodonta uortoni* McLean (1984: 122–123, figs. 1–3; Hickman and McLean, 1990: fig. 40, E) from the Philippines. The new species differs by having much larger size, deviantly coiled whorls, stronger spiral ribs on shoulder of last whorl, more widely spaced spiral ribs, absence of having its nodes aligned in distinct collabral rows, outer lip lirae weaker and corresponding to spiral ribs rather than to their interspaces, columellar teeth much farther apart, anterior tooth weaker, and absence of pustules on the columellar shield.

The new species is similar to the extant *Dauilia insperata* Beu and Climo (1974: 316, figs. 10–13) from New Zealand. The new species differs by two columellar teeth rather than one, parietal callus, no denticles on the outer lip, and no pustules on the columellar shield. The new species has the same shape as *Agathodonta? brooksi* Allison (1955: 411, pl. 40, fig. 6) from upper Aptian strata in Baja California, Mexico. Allison was hesitant about the generic assignment of this species because of the presence of a narrow umbilicus. The new species differs from Allison's species by having much coarser sculpture that weakens rather than strengthens toward the anterior, two rather than a single columellar fold, and no umbilicus. Future collecting might show that Allison's species belongs in genus *Dauilia*.

Subfamily Calliotropinae Hickman and McLean, 1990

Discussion: Kiel and Bandel (2001: 140) stated that they did not find Hickman and McLean's definition of Calliotropinae to be "useful." Instead, they placed *Cidarina* Dall, 1909 in Chilodontinae Wenz, 1938 because *Cidarina* has a thick shell, whereas Calliotropinae is characterized by thin shells.

Genus *Cidarina* Dall, 1909

Type Species: *Margarita cidaris* A. Adams in Carpenter, 1864, by original designation; Pleistocene to Recent, living in Alaska to northern Baja California, Mexico (Squires and Saul, 2003b).

Description: Shell size small to medium, thin. Ovate conical. Anomphalous. Spire elevated. Sculpture of coarse nodes or beads formed at intersections of spiral and collabral sculpture, sculpture weakest anterior to last whorl periphery, aperture nearly circular and oblique. Umbilicus covered by thin columellar callus. Interior nacreous (Squires and Saul, 2003b).

Discussion: In their list of calliotropines having a fossil record, Hickman and McLean (1990: 79–80) did not include the extant genus *Cidarina*. Squires and Goedert (1995) and Squires and Saul (2003) subsequently established that *Cidarina* does have a fossil record. *Cidarina grahami* new species is the earliest *Cidarina*. Only four fossil species of *Cidarina* were previously known: *Cidarina cretacea* Squires and Saul (2003b) of upper Campanian to mid Maastrichtian age from the southern half of California; *Cidarina beta* Squires and Saul (2003b), of mid-Maastrichtian age from central California; *Cidarina antiqua* Squires and Goedert (1995) of middle Eocene age ("Tejon Stage") from southwestern Washington; and *Cidarina cidaris* (A. Adams in Carpenter, 1864) of early Pleistocene to Recent age on the Pacific slope of North America from Alaska to northern Baja California (Grant and Gale, 1931).

***Cidarina grahami* new species**
(Figures 13–17)

Diagnosis: *Cidarina* with medium shell size, spiral ribs nodose posterior to periphery, spiral ribs on base closely spaced, base of last whorl bearing weak spiral ribs with numerous, closely spaced minute nodes.

Description: Shell size medium (height 18 mm, diameter 13 mm, same specimen). Height approximately 1.4 times shell diameter. Ovate conical. Spire elevated, approximately 35% of shell height. Pleural angle 64°. Protocone and upper spire unknown. Teleocone incomplete, at least three whorls. Suture apparently impressed. Spire whorls flat-sided, body whorl convex, rounded but with peripheral angulation. Shell surface covered by spiral ribs: four on ante-penultimate whorl, five on penultimate whorl, six on posterior half (including peripheral angulation) of last whorl, and ten on base of body whorl. Spiral ribs bearing fine beads on upper spire whorls and on base of last whorl; spiral ribs bearing medium-strength beads on penultimate whorl; spiral ribs bearing strong nodes on posterior half of last whorl and on first rib anterior to periphery, with strongest nodes on peripheral angulation. Aperture moderately elliptical. Outer lip thin. Inner lip and columella with grooved callus closing off umbilicus. Callus wash extends over parietal area. Growth lines prosocline, tilted 16° from vertical.

Holotype: RBCM.EH2010.004.00001, height 18 mm, diameter 13.5 mm.

Type Locality: Locality 2 (see Appendix 1).

Geologic Age: Late middle to early late Campanian (*Metaplacenticeras* cf. *pacificum* ammonite zone).

Distribution: Cedar District Formation, upper part, west side of Denman Island off east coast of Vancouver Island, British Columbia (Area 1).

Etymology: The species is named for Raymond Graham, who informed the author about the existence of this species.

Discussion: The new species is based on a single specimen, which has good preservation. The new species is most similar to *Cidarina cretacea* Squires and Saul (2003b: 52, fig. 2.1–2.4) from Maastrichtian strata of central California and (new information) from the upper Campanian to possibly lower Maastrichtian Point Loma Formation at the Carlsbad Research Center, San Diego County, southern California. The new species differs from *C. cretacea* by having more closely spaced spiral ribs with slightly coarser ornament posterior to the periphery on the last whorl, and fewer spiral ribs but with coarser ornament on the base of the last whorl.

Superfamily Turbinoidea Rafinesque, 1815

Family Turbinidae Rafinesque, 1815

Subfamily Colloniinae Cossmann in Cossmann and Peyrot, 1916

Discussion: McLean and Kiel (2007) provided a review of the systematic treatment of turbinoids and colloniines, including some reservations about recent molecular data (e.g., Williams and Ozawa, 2006) concerning these groups. Stemming from Cossmann's early work, it has been recognized (e.g., Hickman and McLean, 1990; McLean and Kiel, 2007) that opercular information is important in dealing with colloniines. Monari et al. (1996) pointed out, however, that in fossil material, information about the operculum is unavailable except in extremely exceptional cases, hence, it is nearly impossible to base a useable paleontological classification on opercula. They argued that other morphological shell characters can be used to distinguish members of colloniines, which constitute a rather homogeneous group in having a thick shell that is smooth or weakly ornamented with spiral threads.

Genus *Afrollonia* Adegoke, 1977

Type Species: *Afrollonia nigerensis* Adegoke, 1977, by original designation; Paleocene, southwestern Nigeria.

Description: Shell size small. Turbiniform. Phancromphalous. Spire low to moderately high. Ramp broad. Protoconch small, smooth, and bilbous. Teleoconch sculpture consisting of few fine spiral ribs. Anterior end of columellar lip slightly expanded and subangulate

where intersected by carination of umbilical margin; umbilical rim usually prominent and crenulated, interior of umbilicus with periumbilical cord ending in a wide process on columella (Adegoke, 1977; Kase, 1984).

Discussion: *Afrollonia* is similar to genus *Collonia* J. E. Gray in M. E. Gray, 1850, but differs from the latter by having sculpture. Although Adegoke (1977) assigned *Afrollonia* to subfamily Colloniinae, Kase (1984) assigned this genus to subfamily Margaritinae Stoliczka, 1868 based on the similarity of *Afrollonia* to *Atira* Stewart, 1927, which was originally proposed as a subgenus of *Margarites* J. E. Gray, 1847 (*ex* Leach ms.). This similarity is superficial because *Afrollonia* is characterized by a periumbilical cord; no such feature is present on *Atira*.

Afrollonia has been reported only from Paleocene strata in Egypt, Nigeria, and Togo, Africa (Adegoke 1977). *Afrollonia elderensis* new species, described below, is the earliest confirmed record of this genus and its only record in the Western Hemisphere.

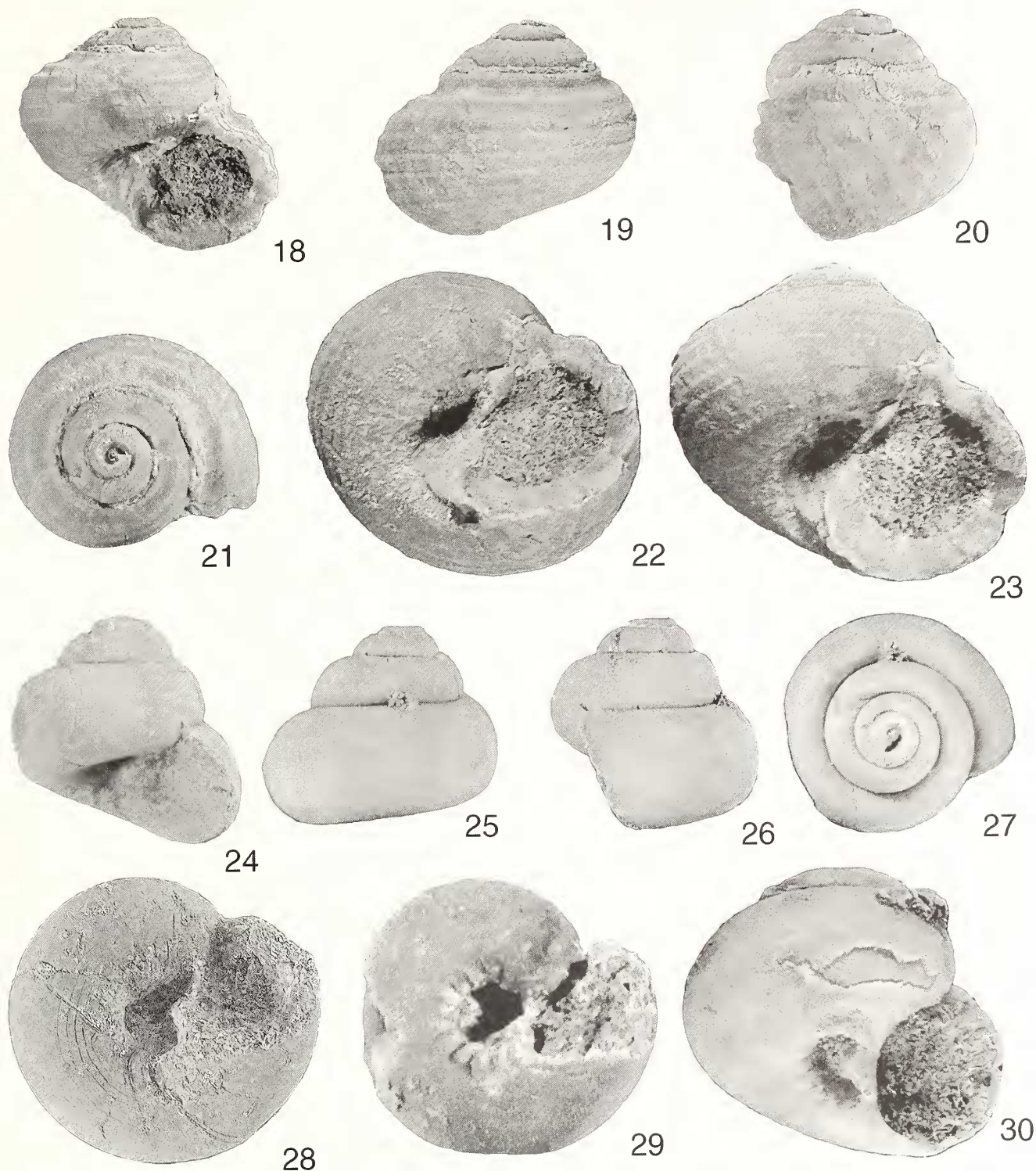
***Afrollonia elderensis* new species**

(Figures 18–23)

Diagnosis: *Afrollonia* with rounded whorls, suture collared, spiral ribs moderately widely spaced, umbilicus rim weakly demarcated.

Description: Shell size small (up to height 6 mm, diameter 6.5 mm, same specimen). Height slightly less than shell diameter. Turbiniform. Phancromphalous. Spire moderately low, height approximately 28% of shell height. Pleural angle approximately 105°. Protoconch unknown. Teleoconch consisting of approximately four whorls. Suture impressed and rimed by thin, high collar on succeeding whorl. Whorls rounded. Ramp on last whorl concave. Sculpture on spire whorls consisting of approximately three to four, narrow but widely spaced spiral threads with smooth, concave interspaces. Sculpture on last whorl consisting of several thin, prominent, and widely spaced spiral ribs; approximately five spiral ribs between suture and base on last whorl. Interspace between collar and posteriormost spiral rib widest and most concave. Base not clearly demarcated from sides of last whorl. Sculpture on base consisting of seven spiral ribs, most being weaker than those on periphery but becoming anteriorly stronger. Aperture circular. Outer and inner lips flared. Peristome continuous. Umbilicus semi-lunar. Rim of umbilicus subtle and demarcated near inner lip by short but strong and noded spiral rib increasing in strength toward anterior end of aperture. Periumbilical cord smooth, extending short distance into umbilicus on its left side. Columellar lip reflected toward umbilicus adjacent to terminus of periumbilical cord. Anterior end of columellar lip slightly expanded and subangulate where intersected by carination of umbilical margin. Growth lines prosocline.

Holotype: LACMIP 13701, height 6 mm, diameter 6.7 mm.



Figures 18–30. New collonines. Specimens coated with ammonium chloride. 18–23. *Afrollonia eldicensis* new species, holotype LACMIP 13701, LACMIP loc. 28777, height 6 mm, diameter 6.7 mm. 18. Apertural view. 19. Abapertural view. 20. Right-lateral view. 21. Apical view. 22. Umbilical view. 23. Oblique umbilical view. 24–30. *Antillocollonia bos* new species 24, 25, 26, 27. Holotype LACMIP 13702, LACMIP loc. 10742, height 6.5 mm, diameter 6.5 mm. 24. Apertural view. 25. Abapertural view. 26. Right-lateral view. 27. Apical view. 28. Paratype LACMIP 13703, Stewart's (1946) Arroyo Pinoso, loc. 97, umbilical view, diameter 7 mm. 29. Paratype LACMIP 13704, LACMIP loc. 10763, umbilical view, diameter 5 mm. 30. Paratype LACMIP 13705, LACMIP loc. 10742, oblique umbilical view, diameter 5.8 mm.

Type Locality: LACMIP 28777.

Geologic Age: Late Albian.

Distribution: Reworked Albian material in the Turonian Venado Sandstone, Elder Creek, Tehama County, northern California (Area 4).

Etymology: Named for its occurrence in Elder Creek area, Tehama County, northern California.

Discussion: The new species is based on a single specimen, which has good preservation. The exact location of the type locality of the new species is not known. It is a boulder from a conglomerate of early Turonian age, but, according to the LACMIP locality information, the fauna in the boulder is of late Albian age. Reworked late Albian fossils in this same stratigraphic unit are known elsewhere in the Cretaceous section of northern Sacramento Valley, northern California (Matsumoto, 1960: 34–35; Popenoe et al., 1960: chart 10e; Squires and Saul, 2006).

The new species is most similar to *Afrollonia nigeriensis* Adegoke (1977: 68–69, pl. 11, figs. 10–15) from Paleocene rocks in southwest Nigeria but differs from Adegoke's species by having a flatter ramp, last whorl not ornamented by three prominent spiral ribs with much finer spirals in between, base not angulate, and umbilical rim not well demarcated.

Kase (1984) reported *Afrollonia matsushimensis* Kase (1984: 60–61, pl. 6, figs. 5, 8–10) from upper Aptian to lower Albian strata in northeastern Japan. Kase's species, however, does not have a periumbilical ridge nor a thickening of the columella where this ridge intersects the columella; hence, his species does not belong in this genus.

Genus *Antilocollonia* Sohl, 1998

Type Species: *Antilocollonia brujoensis* Sohl, 1998, by original designation; late Campanian to Maastrichtian, Puerto Rico.

Description: Small size small (less than 10 mm high) but sturdy. Turbinate. Phaneromphalous. Teleoconch whorls smooth. Aperture circular. Peristome continuous. Periumbilical cord prominent and smooth. Columellar lip thickest where intersected by periumbilical cord. Anterior end of columellar lip slightly expanded and subangulate where intersected by carination of umbilical margin. Exterior of operculum pustulose, ridge, and with prominent central pit (Sohl, 1998). Rim of umbilicus with or without crenulations.

Discussion: *Antilocollonia* is similar to *Collonia* M. E. Gray, 1850 but differs from the latter by having an auricular (earlike) projection high on the columella and lacking beads on the umbilical rim.

Antilocollonia has been reported before only from upper Campanian to Maastrichtian strata in Puerto Rico (Sohl, 1998). *Antilocollonia bos* new species, described

below, is the earliest record of this genus and is also its first record from the Pacific slope of North America.

***Antilocollonia bos* new species**

(Figures 24–30)

Diagnosis: *Antilocollonia* with umbilicus rim usually coincident with coarsely noded spiral cord, anteriormost two nodes strongest.

Description: Shell size very small (up to height 6.5 mm, diameter 7 mm, same specimen). Height approximately same as shell diameter. Turbinate. Phaneromphalous. Spire moderately high, height approximately 20% of shell height. Pleural angle 89°. Protoconch unknown. Teleoconch consisting of six whorls. Suture impressed. Whorls convex. Shoulder very narrow. Shell surface smooth; base of last whorl can have five to six, very faint, flat, and widely spaced spiral bands with incised striae between them. Aperture circular. Outer lip thin, inner lip thicker. Peristome continuous. Umbilicus narrow. Rim of umbilicus angulate and usually demarcated by coarsely noded spiral rib, nodes commonly increasing in strength toward anterior end of aperture; anteriormost node strongest; nodes on posterior part of rim generally less well developed on adult specimens; spiral rib terminates at columellar lip. Periumbilical cord prominent, smooth. Columellar lip thickest where intersected by periumbilical cord. Anterior end of columellar lip slightly expanded and subangulate where intersected by carination of umbilical margin. Growth lines prosocline.

Holotype: LACMIP 13702, height 6.5 mm, diameter 6.5 mm.

Paratypes: LACMIP 13703–13705.

Type Locality: LACMIP 10742.

Geologic Age: Turonian.

Distribution: LOWER TURONIAN: Redding Formation, Bellavista Sandstone Member, east of Redding, Shasta County, northern California (Area 3). MIDDLE TURONIAN: Redding Formation, Frazier Siltstone Member, east of Redding, Shasta County, northern California (Area 3). TURONIAN (UNDIFFERENTIATED): Panoche Formation, Arroyo Pinoso, Reef Ridge area, Fresno County, central California (Area 7).

Etymology: Named for its occurrence in Cow Creek area east of Redding, Shasta County, northern California; *bos*, Latin, meaning cow.

Discussion: The examined material consisted of 52 specimens. Preservation is good although the fragile periumbilical cord is usually missing or incomplete. Some specimens do not have nodes on the rim of the umbilicus.

The new species is remarkably similar to *Antilocollonia brujoensis* Sohl (1998: 47–48, pl. 3, figs. 17–22)

from upper Campanian to Maastrichtian strata in Puerto Rico. The main difference is that the new species commonly has a coarsely noded spiral rib on the rim of the umbilicus.

The new species superficially resembles the trochid *Garramites nitidus* Stephenson (1941: 262, pl. 47, figs. 17–19) from the Nacatoch Sand, eastern Texas. Stephenson (1941) assigned this sand to the Maastrichtian, but Akers and Akers (1997: fig. 2) assigned it to the upper Campanian. Genus *Garramites* Stephenson, 1941, which is monotypic, is characterized by a nearly smooth small shell having a wide umbilicus with an angulated, rather coarsely crenulated rim. Within the umbilicus is a broad, shallow, spiral sulcus that closely rims the row of prominent crenulations. *Anticollonia bos* differs from *G. nitidus* by having a periumbilical cord and commonly having a beaded ridge that rims the umbilicus. In addition, *A. bos* does not possess a spiral sulcus that closely rims this beaded ridge.

The occurrence of the new species in the Panoche Formation in Arroyo Pinoso of the Reef Ridge area, Fresno County, central California is based on the author's observation of specimens from Stewart's (1946: 88) locality 97. Stewart noted that W. P. Popenoe identified the fauna from this locality as Turonian in age, and Popenoe et al. (1960: 1521) reiterated this interpretation.

Family Turbinidae? Rafinesque, 1815

Subfamily Tegulinae Kuroda, Habe, and Oyama, 1971

Discussion: This subfamily was previously generally believed to be a trochid subfamily (e.g., Hickman and McLean, 1990), but, based on molecular studies of extant taxa by Williams et al. (2008), it has been provisionally assigned to the Turbinidae.

Genus *Tegula* Lesson, 1835 *sensu lato*

Type Species: *Tegula peltiserpensis* (Wood, 1828), by original designation; Recent, west coast of Central America to Gorgona Island, Colombia, South America (Keen, 1971).

Description: Shell size medium, solid. Globose to conic. Phaneromphalous. Shells smooth to sculptured, with sculpture consisting of broad, coarsely beaded spiral ribs. Base flattened. Peristome discontinuous. Anterior end of columella with one or more teeth. Umbilicus ranging from open to closed. Interior nacreous.

Discussion: Based on reports by earlier workers (Wenz, 1938; Keen, 1960), the geologic range of *Tegula* is Miocene to Recent. Subsequently, other workers (Bandel and Stinnesbeck, 2000; Kiel and Bandel, 2001; Squires and Saul, 2005) demonstrated that *Tegula* has a Cretaceous record, and the earliest known species is *Tegula jeanae* Squires and Saul, 2005 of early Campanian age in northern California.

***Tegula daileyi* new species**
(Figures 31–33)

Diagnosis: *Tegula* with three to four widely spaced, narrow spiral ribs on penultimate and last whorls.

Description: Shell size medium (height 19 mm, diameter 19 mm, same specimen). Height approximately same as shell diameter. Turbinate. Phaneromphalous. Spire unknown. Suture impressed. Penultimate and last whorls convex with three to four narrow, prominent spiral ribs; widely and subequally spaced, with two anteriormost ribs slightly closer to each other. Base flattened, apparently smooth. Aperture circular. Peristome interrupted. Outer lip moderately thin. Inner lip with single prominent tooth. Umbilicus small. Growth lines prosocline, tilted 43° from vertical.

Holotype: LACMIP 13706, height 20.4 mm, diameter 20.7 mm.

Type Locality: LACMIP 24123.

Geologic Age: Late Campanian.

Distribution: Jalama Formation, Santa Barbara County, California (Area 8).

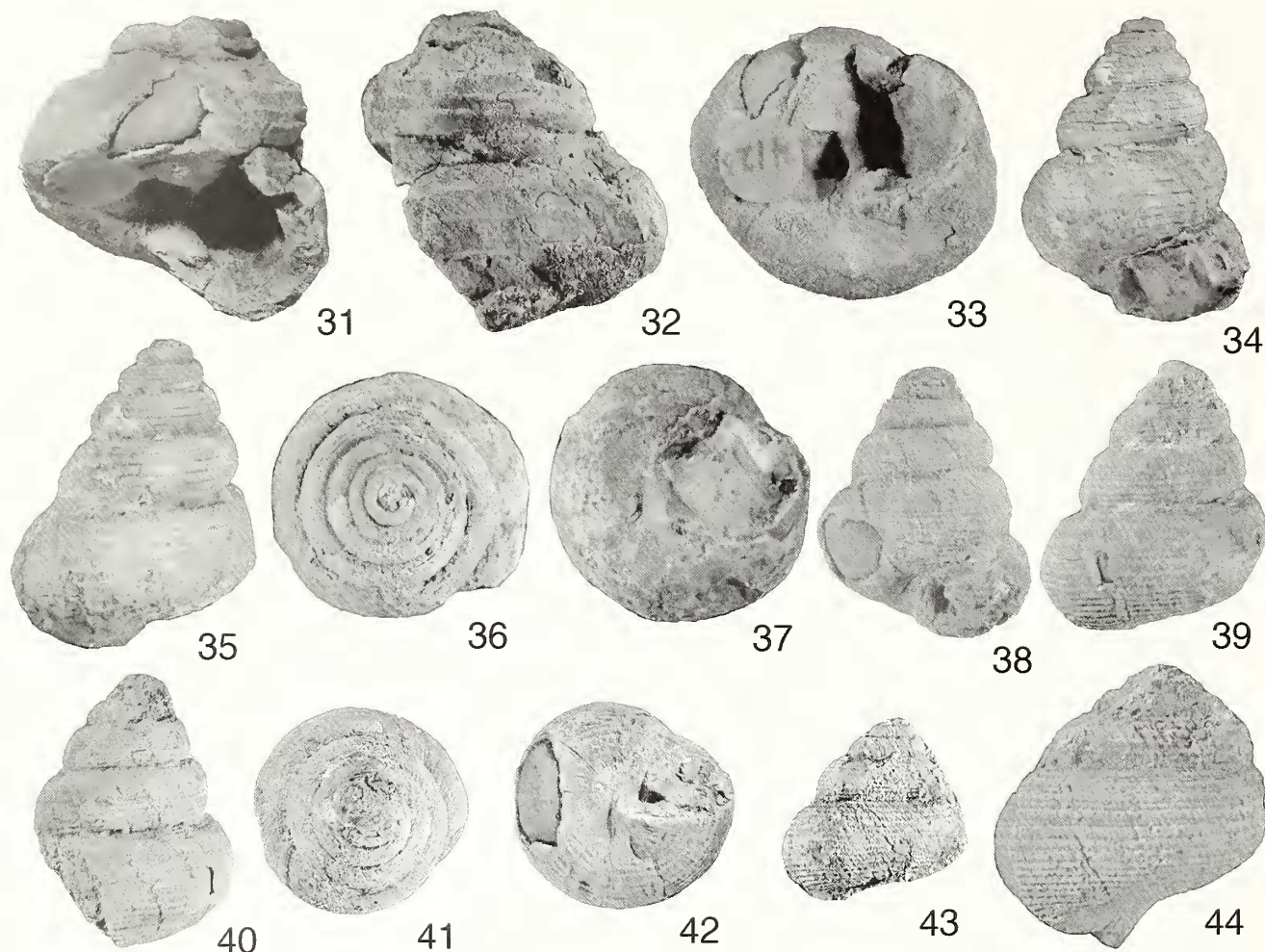
Etymology: The species is named for D.H. Dailey who worked on the molluscan fauna from the Jalama Formation.

Discussion: The new species is based on a single specimen, which is crushed and missing its spire. It is most similar to the extant *Tegula mariana* (Dall, 1919: 359; Keen, 1971: fig. 105), known mainly from the Gulf of California, Mexico, but differs from Dall's species by having a larger size, higher spire, and a more prominent columellar tooth.

The new species differs from *Tegula jeanae* Squires and Saul (2005: 135–136, figs. 3–5), of early Campanian age from northern California, by having sculpture, an open umbilicus, more prominent columella tooth, no secondary denticles in the columella, and no raised lip along the basal edge of the interior of the last whorl. Bandel and Stinnesbeck (2000) reported *Tegula ovallei* (Philippi, 1887) from Maastrichtian strata in central Chile. The new species differs by not having numerous, closely spaced and beaded spiral ribs. Kiel and Bandel (2001) reported *Tegula? simplex* (Quintero and Revilla, 1966) from the Campanian (undifferentiated) strata of northern Spain. The new species differs by having a much larger shell, an umbilicus, and an absence of numerous, closely spaced spiral ribs.

Subfamily Margaritinae Stoliczka, 1868

Discussion: This subfamily was previously generally believed to be a trochid subfamily (e.g., Hickman and McLean, 1990; Warén and Bouchet in Bouchet and Rocroi, 2005), but, based on molecular studies of extant taxa by Williams et al. (2008), it has been provisionally assigned to the Turbinidae. According to Williams et al. (2009), Margaritinae is not monophyletic.



Figures 31–44. New teguline and new margaritines. Specimens coated with ammonium chloride. **31–33.** Teguline *Tegula daileyi* new species, holotype LACMIP 13706, LACMIP loc. 24123, height 20.4 mm, diameter 20.7 mm. **31.** Apertural view. **32.** Right-lateral view. **33.** Umbilical view. **34–37.** *Pupillaria encina* new species, holotype SDSNH 11082, SDSNH loc. 152, height 11.7 mm, diameter 8.6 mm. **34.** Apertural view. **35.** Abapertural view. **36.** Apical view. **37.** Umbilical view. **38–44.** *Pupillaria lomana* new species, holotype LACMIP 13707, LACMIP loc. 5571, height 12.2 mm, diameter 9.6 mm. **38.** Apertural view. **39.** Abapertural view. **40.** Right-lateral view. **41.** Apical view. **42.** Umbilical view. **43–44.** Paratype LACMIP 13708, LACMIP loc. 5571, juvenile, height 6.8 mm, diameter 7 mm. **43.** Abapertural view. **44.** Left-lateral view.

Genus *Pupillaria* Dall, 1909

Type Species: *Trochus pupillus* Gould, 1849, by original designation; Recent, Bering Sea to southern California.

Description: Shell size small to moderately small, thin. Turbiniiform to ovate-conical. Phaneromphalous. Spiral ribs raised but flattened with narrow interspaces. Peristome discontinuous. Columella smooth. Outer lip unthickened. Umbilicus slit-like to nearly closed. Interior nacreous.

Discussion: Workers (e.g., Wenz, 1938; Palmer, 1958; Keen, 1960) traditionally used *Pupillaria* as a subgenus of *Margarites*. The narrowness of the umbilicus of *Pupillaria*, however, warrants that *Pupillaria* have generic standing. According to Wenz (1938) and Keen

(1960), the geologic range of *Pupillaria* is Miocene to Recent. The new species *Pupillaria encina* and *Pupillaria lomana*, described below, extend the earliest record of *Pupillaria* to the late Campanian.

Pupillaria encina new species

(Figures 34–37)

Calliomphalus? sp. Sundberg and Riney, 1984: table 1.

Diagnosis: *Pupillaria* with ovate-conic shape and broad and prominent spiral ribs.

Description: Shell size small (up to height 11.7 mm, diameter 8.6 mm, same specimen). Height approximately 1.3 times shell diameter. Ovate conical. Phaneromphalous. Spire high, approximately two-thirds of shell height. Pleural angle 52° . Protoconch unknown.

Teleoconch approximately six whorls. Suture impressed. Shoulder rounded. Sculpture consisting of many broad spiral ribs; five on upper spire whorls, seven on penultimate whorl, approximately 13 on last whorl and becoming narrower anteriorward of periphery. Interspaces very narrow and incised. Aperture circular. Peristome discontinuous? Umbilicus slit-like and extremely narrow. Growth lines prosoline, tilted 20° from vertical.

Holotype: SDSNH 11082, height 11.7 mm, diameter 8.6 mm.

Type Locality: SDSNH 152.

Geologic Age: Late Campanian to possibly early Maastrichtian.

Distribution: Point Loma Formation, Cañon de Las Encinas, near Carlsbad, San Diego area, San Diego County, southern California (Area 9).

Etymology: The new species is named (noun in apposition) for its occurrence at Cañon de Las Encinas; Spanish, *encina*, meaning “oak.”

Discussion: The new species is based on a single specimen, which is the non-figured specimen of *Callionophalus*? sp. reported by Sundberg and Riney (1984) from the Carlsbad Research Center, San Diego County. This species differs from *Pupillaria lomana* new species by having wider and more prominent spiral ribs and no interrib between the spiral ribs on the posterior part of the last whorl.

***Pupillaria lomana* new species**
(Figures 38–44)

Diagnosis: *Pupillaria* with spiral ribs narrow and single fine interrib between spiral ribs on posterior part of last whorl.

Description: Shell size small (up to height 12 mm, diameter 9.5 mm, same specimen). Height approximately 1.3 times shell diameter. Ovate conical. Phaneromphalous. Spire high, approximately two-thirds of shell height. Pleural angle 54°. Protoconch unknown. Teleoconch approximately six whorls. Suture impressed. Shoulder rounded. Sculpture consisting of numerous closely spaced, narrow spiral ribs; six to seven on spire whorls, 16 to 18 on last whorl and becoming narrower anteriorly of periphery. Spiral ribs just posterior of suture strongest and minutely beaded. Spiral ribs on shoulder weak, approximately two and widely spaced. Interspaces between spiral ribs on posterior of last whorl with single spiral riblet. Aperture circular. Outer lip thin; inner lip very slightly thickened anteriorly. Peristome discontinuous? Umbilicus slit-like, nearly closed. Growth lines prosoline, tilted 25° from vertical.

Holotype: LACMIP 13707, height 12.2 mm, diameter 9.6 mm.

Paratype: LACMIP 13708.

Type Locality: LACMIP 5571.

Geologic Age: Late Campanian to possibly early Maastrichtian.

Distribution: Moreno Formation, “Quinto Silt” member or possibly “Garzas Sand” member, Los Banos Creek, Merced County, northern California (Area 6); Point Loma Formation at the Carlsbad Research Center, Carlsbad, San Diego County, southern California (Area 9); Cabrillo Formation (in a reworked clast from the underlying Point Loma Formation), La Jolla, San Diego County, southern California (Area 10).

Etymology: The new species is named for the Point Loma Formation.

Discussion: The examined material consisted of four specimens. Preservation is good. The new species is like the specimen of the extant *Pupillaria pupilla* (Gould, 1849) illustrated by Hiekman and McLean (1990, fig. 48, two figs.), but differs from their specimen by having much more impressed sutures.

The new species resembles *Margarites kasei* Kiel and Bandel (2001:31, pl. 5, figs. 16–17) from the Campanian (undifferentiated) of northern Spain, but the new species differs by having a wider pleural angle, wider spire whorls, and much stronger spiral sculpture.

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APPENDIX 1 – TYPE LOCALITIES OF THE NEW SPECIES

Listed quadrangle maps are U. S. Geological Survey maps. Detailed information about the other cited localities is available via the following: LACMIP website: <http://ip.nhm.org/ipdatabase/locality_show>; UCMP website: <<http://ucmpdb.Berkeley.edu/loc.html>>; and CAS: contact the collections manager.

Locality 1. “Lower Quarry,” just west of Nanaimo, 49°11.735' N, 124°6.143' W, at the Moto-cross racetrack on Dumont Road, east coast of Vancouver Island, British Columbia. Haslam Formation, upper part. Age: Latest Santonian. Collector: Joe Haegert, 1987.

Locality 2. Gray siltstone, slightly north of “White House Site,” near ferry terminal, west shore of Denman Island, 49°32'16.2" N, 124°49'37.7" W, off east coast of Vancouver Island, British Columbia. Cedar District Formation, upper part. Age: Late middle Campanian to early late Campanian (*Metaplagenticeras* cf. *pacificum* Zone). Collector: R. Graham, March 28, 2005.

LACMIP 5571. Elevation 10 ft., gray argillaceous and coarse sandstone concretion (Point Loma Formation lithology) on beach, approximately 20 m N of concrete/gully at W most end of Forward St., La Jolla, La Jolla Quadrangle (1953, 7.5 minute), San Diego, southern California. Clast of Point Loma Formation reworked into the Cabrillo Formation. Age: Late Campanian or possibly early Maastrichtian. Collector: B. Welton, August 16, 1977.

LACMIP 10742. Fine-grained sandstones and sandy shales on S bank of Little Cow Creek at the approximate

S line of the SE 1/4 of the SW 1/4 of section 36, T. 33 N., R. 3 W., Millville Quadrangle (15 minute, 1953), Shasta County, California. Redding Formation, Frazier Siltstone Member. Age: Middle to late Turonian. Collectors: W. P. Popenoe and G. P. Zebal, August 1, 1941.

LACMIP 10798. Lat. $40^{\circ}38'00''$ N, long. $122^{\circ}04'30''$ W. Massive sandstones interbedded with conglomerates on S side of high E-W trending ridge, 998 m (3275 ft.) $S54^{\circ}59'W$ from SE corner of section 10, T. 32 N., R. 2 W., Millville Quadrangle (15 minute, 1953), south side of Oak Run Valley, Shasta County, northern California. Redding Formation, Member V. Age: Early Santonian. Collectors: W. P. Popenoe and C. W. Ahlroth, July 1, 1936.

LACMIP 24123. Hard, medium to coarse-grained, gray pebbly arkosic sandstone, near of ridge, 525 ft. north of Jalama Creek, elevation 625 ft., 2.42 mi. E and 0.68 mi. S of the Jalama Ranch Headquarters, 2.29 mi. W and 0.42 mi N of the SE corner of the topographic sheet, Lompoc Hills Quadrangle (1947), Santa Barbara County, California. Jalama Formation. Age: Late Campanian. Collector: D. Dailey, August, 1958.

LACMIP 28777. From boulder in basal "Chico" conglomerate, Elder Creek, Tehama County, northern California. Collector: P. R. Reinhart.

SDSNH 152. Cañon de Las Encinas, Rancho Agua Hedionda, San Diego County, California. Point Loma Formation. Age: Late Campanian or possibly early Maastrichtian. Collector: F. Stephens, March 29, 1929.